Parabolic Flight Testing of Aeroponic Plant Growth Systems and Super Omniphobic Surface Coatings

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Nomenclature

I	=	moment of inertia
b	=	beam width
h	=	beam height
c	=	perpendicular distance to the neutral axis
M	=	bending moment about the neutral axis
σ	=	maximum stress
r(uv)	=	shear force per bolt
P	=	concentric force
n	=	number of bolts in the connection
r(ut)	=	tensile force in each bolt above the neutral axis
n'	=	number of bolts above the neutral axis
d	=	moment arm
$\sigma(x)$	=	tensile stress
$\sigma(y)$	=	compressive stress
$\tau(xy)$	=	shear stress

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I. Abstract

The purpose of this project is to gain valuable data from three separate experiments. One being an aeroponics watering system, another being a PONDS passive watering system, and the last a super omniphobic surface coating apparatus.

There are two aeroponics watering systems that feed water and nutrients to "plant roots" inside of a contained box. The walls inside of the contained boxes have different surface textures and shapes but each contain the same nozzle and compressor set up as a control.

There is one PONDS passive watering system that feeds water from a reservoir to a porous substrate utilizing wicking materials.

There is one super omniphobic surface coating apparatus that feeds water into an apparatus allowing the water to make contact with three individual compartments in which glass beads with different coatings are carefully placed between two glass slides.

The outcome will contribute to the advancement in self sustainment for space exploration. The status of the project when I started was to get the system built and ready for flight come November. My intended contributions are to assist with the build of the system.

II. Introduction

A CAD assembly for the super omniphobic surface coating apparatus had been previously made by Prital Thakrar which is shown below:

Figure 1. CAD assembly made by Prital Thakrar in Creo version 2

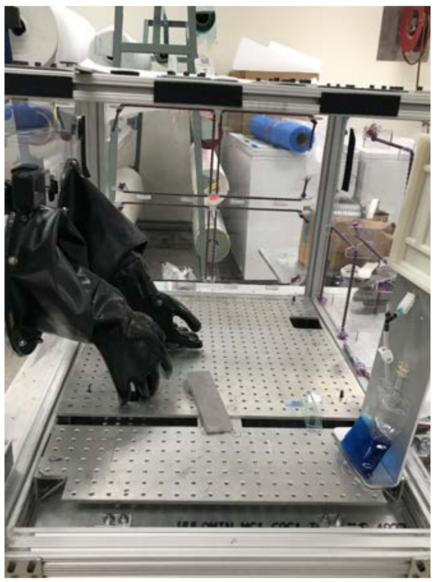

Figure 2. Interior of glove port box that secures all the projects during flight from Gadsden State Community College.

Each of the projects must be mounted and secured according to Zero-G flight requirements into the glove port box shown above which was designed and manufactured by Gadsden State Community College.

III. Experimental Setup

Prital Thakrar's design of the super omniphobic surface coating apparatus was 3D printed using an Objet, and was than tested to ensure it was watertight. We also simulated zero gravity by laying the apparatus horizontal to see how much water would climb towards to top.

Figure 3. a) 3D print of Prital Thakrar's

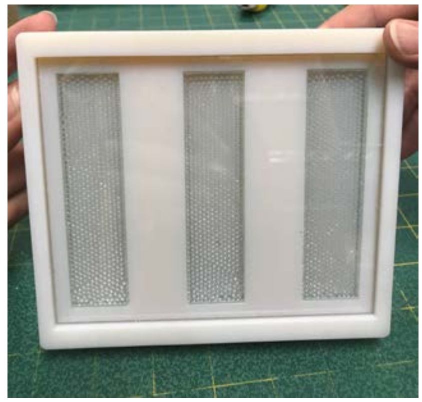

Figure 3. b) first test design of the super omniphobic coating apparatus with uncoated glass beads

The experiment passed the watertight seal test but needed to be redesigned in order to allow a reservoir above and below the three chambers shown in the figure below. Adding this allows both a visual that the water level is just touching the glass beads as well as to ensure that water would not leak out of the top of the apparatus.

Figure 4. a) Redesign of original super omniphobic coating apparatus

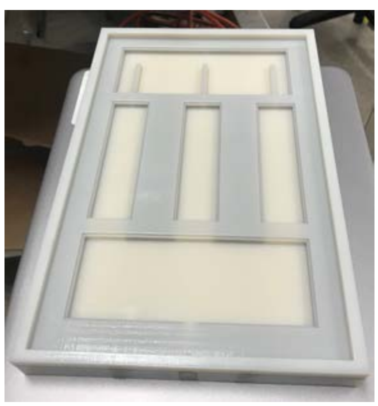

Figure 4. b) 3D print of super omniphobic coating apparatus redesign

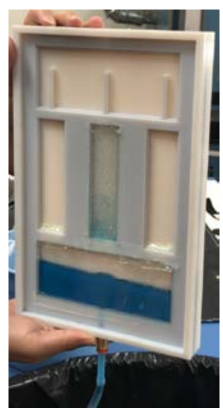

Figure 4. c) Testing watertight seal

Figure 4. d) Final design with coated beads

After the success of sealing and testing this design, a design to mount this experiment to the Zero-G flight box was designed and manufactured. The material used for the mount is 3/16" 5052 aluminum and the following pictures show the CAD as well as the final product:

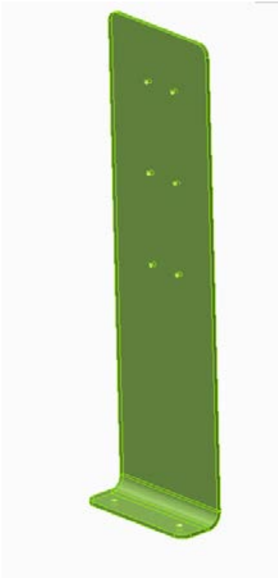

Figure 5. a) CAD of super omniphobic coating apparatus mount

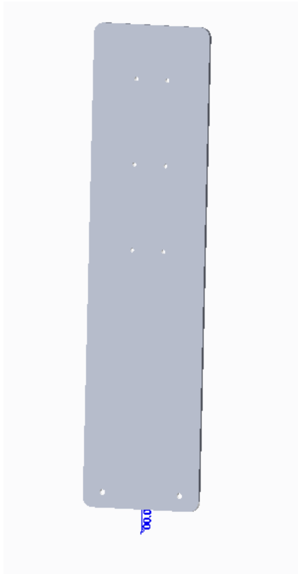

Figure 5. b) CAD of super omniphobic coating apparatus mount converted to sheet metal and unbent

Figure 5. c) Final product of the mount with the apparatus secured to it.

During the design process it became obvious that a separate mounting plate for the two compressors must be made. Following the requirements, the mounting plate needed to be aluminum having a minimum area of 24" x 24" and a thickness of .5". After taking the proper measurements and allowing clearance for holes the following CAD was made:

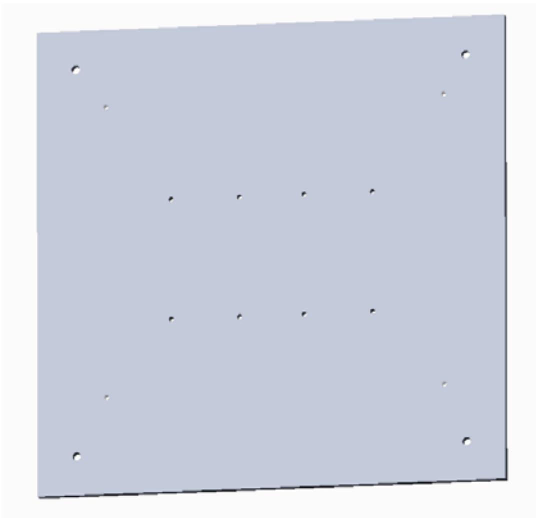

Figure 6. CAD for compressor mounting plate made in Creo Version 2.

A waterjet was used to cut these dimensions and holes out of a larger sheet of aluminum which was then deburred for flight crew safety, a picture of it can be seen in fig. 8.

To ensure that neither the compressors nor flight crew would be damaged a cover for the compressor mounting plate needed to be made. After taking the measurements needed to allow enough height for the compressors the following CAD was made:

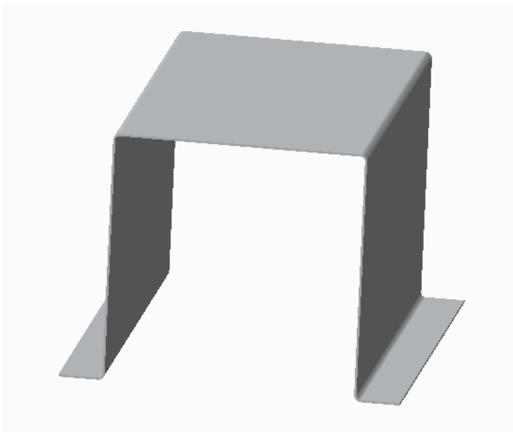

Figure 7. a) CAD of compressor cover plate made in Creo version 2

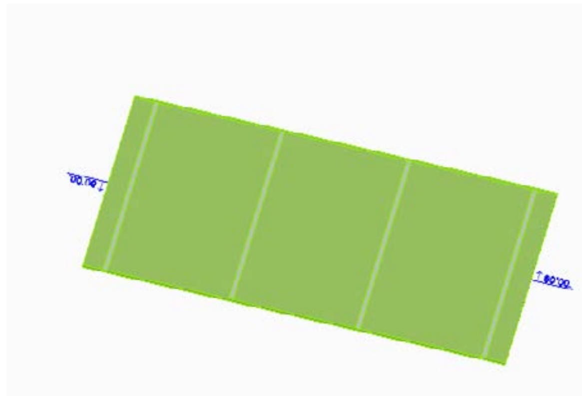

Figure 7. b) CAD of compressor cover plate converted to sheet metal and unbent

The following load calculations were used to determine what material and thickness would be needed:

$$I = \frac{1}{12}bh^3;\ c = \frac{h}{2};\ M = \frac{P\ell}{4};\ \sigma = \frac{Mc}{I}$$

The following bolt calculations were used to determine the bolt dimensions needed to secure the cover to the mounting plate according to Zero-G requirements:

$$r(uv) = \frac{P}{n};\ r(ut) = \frac{Pe}{n'd};\ \sigma = \frac{\sigma(x)+\sigma(y)}{2} + \left(\left(\frac{\sigma(x)-\sigma(y)}{2}\right)^2 + \left(\tau(xy)\right)^2\right)^{\frac{1}{2}}$$

After confirming calculations, it was determined that 3/16” 5052 aluminum sheet metal would be both sufficient and easily obtainable to make the compressor cover. Using the bolt calculations it was determined that ¼ “ – 20 bolts would satisfy the requirements. In the following picture you can see the final cover in which s waterjet was used to cut the dimensions needed, a brake was used to bend the aluminum sheet, and finally a power drill was used to make holes to mount the cover to the mounting plate.

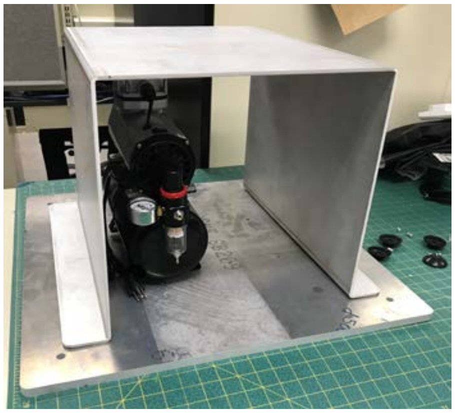

Figure 8. Compressor mounting plate with cover. Only one compressor is shown, another compressor was mounted next to the one shown.

For the two aeroponics systems as well as the PONDS passive watering system holes had to be drilled into their polycarbonate mount in order to line up with the plate it would be mounted to inside of the box. A height marker and a power drill were used to accurately make a pilot hole before drilling out the actual drill size needed. The following pictures show the results:

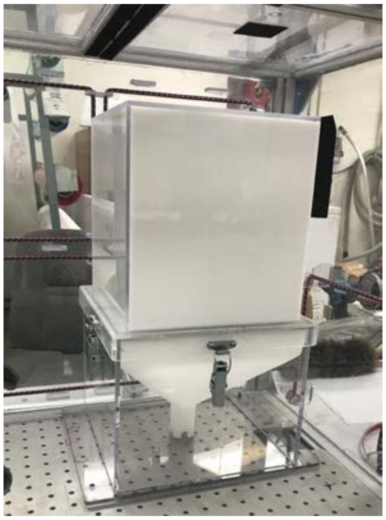

Figure 9. a) Aeroponics system with holes drilled in the polycarbonate mount

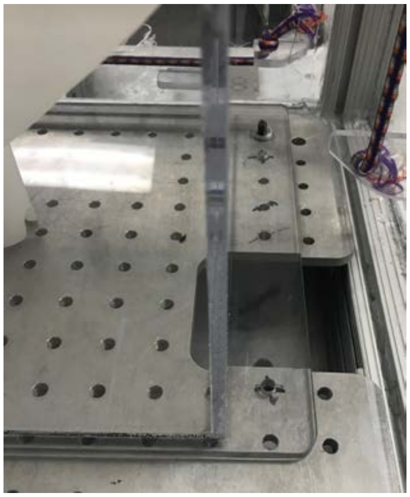

Figure 9. b) Close up of polycarbonate mount with holes

After getting each of the projects mounted inside of the box GoPros and lighting was placed as well as foam around the edges of the box for flight crew safety, see pictures below:

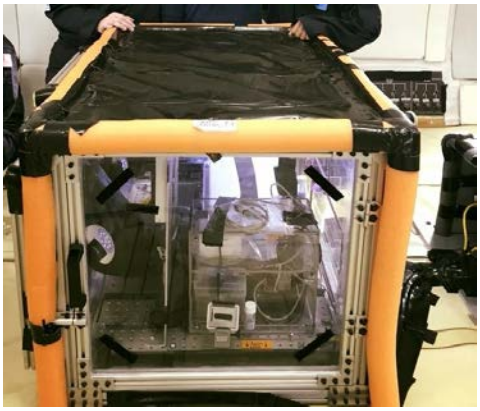

Figure 10. a) Glove port box with projects, lighting, and GoPros mounted

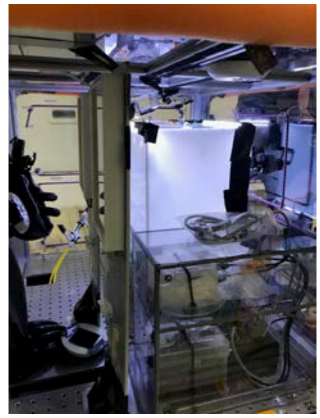

Figure 10. b) Interior of glove port box with all experiments, lights, and GoPros mounted

IV. Results and Discussion

On flight day the hardware passed Zero-G flight inspection and was able to board the flight for testing. The GoPro video data is still being assessed but we have been able to evaluate some of the results from the super omniphobic coating apparatus. Below you can see some screenshots taken from the GoPro footage which was filmed while the experiment was in zero gravity. There are some air bubbles in the reservoir but as you can see in the pictures the air bubble shifts during each parabola and has no effect on whether water climbs up the glass beads or not. This experiment performed the way that was expected in that the super omniphobic coatings altered the fluid flow dynamics to a larger degree in zero gravity.

Figure 11. a) Super omniphobic coating apparatus while in zero gravity with air bubble in the reservoir on the left side.

Figure 11. b) Super omniphobic coating apparatus while in zero gravity with air bubble in the reservoir on the right side.

V. Acknowledgements

I would like to acknowledge Mark Lane who gave me several tips, including but not limited to leaving extra room for clearance, when it came to design a part in Creo that would be 3D printed in the Objet.

I would like to acknowledge both David McLaughlin and James Niehoff whom both gave me hands on instructions on how to use a hand tap as well as a power drill. Along with knowledge of how to read a drill tap chart, they both gave me some machinist tips when it came to both designing and manufacturing.

I would like to acknowledge Wenyan Li who gave me a better understanding of hydrophilic and hydrophobic coatings in relation to how they react with water as well as reviewed my report.

I would like to acknowledge Prital Thakrar who gave me several tips on how to work within Creo, including but not limited to how to turn a part into sheet metal for bending. She also gave me several suggestions on how to calculate the load for the cover.

I would like to acknowledge Oscar Monje who gave me some tips on project placement and provided me with pictures.

I would like to acknowledge Dr. Luke Roberson who gave me guidance and tips on forming this final report.

VI. References

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